Electricity from sea waves

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Abstract

This project aims to exploit the mild and renewable source of energy produced by the waves of the sea. It is preceded by information aimed at raising students' sensitivity on environmental awareness and alternative forms of energy production. The phenomenon of electromagnetic induction is mentioned, on which the operation of the experimental setup of the project is based. Here are the instructions for making the arrangement with materials found in a school laboratory. Through it, ripple is created in water and electricity is produced, which lights up a led or charges a capacitor.

Introduction

Energy in all its forms is an integral part of human life. Due to rapid growth, the demand for energy has skyrocketed and there has been excessive use of fossil fuels. The specific materials have limited reserves, and their combustion has a harmful effect on the Earth and by extension on the man himself. The consequence of this was the need to turn to nature in search of energy, from inexhaustible sources, such as the sun, the wind and the sea. Sea wave energy is obtained from a renewable source.

Receiving and using it can bring multiple benefits. Thus, the sea also participates in the production of electricity from water. Many countries are trying to harness the power of waves and the huge amounts of mechanical energy that travel with them (without transferring matter) to convert them into kinetic and then electrical energy.

Students in groups will collect and present information on:

• Renewable and non-renewable energy sources

• Sea wave energy (Origin, Exploitation)

In the school laboratory using simple instruments and applying basic concepts of Physics, an experimental device will be constructed that converts the energy of water waves into electrical energy.

Theoretical Framework

The phenomenon of the creation of an electric current, or more precisely the creation of an electromotive force, from the magnetic field is called electromagnetic induction. It was discovered in 1831 by two scientists, unknown to each other, the Englishman Faraday and the American Henry, and it brought significant progress both to the science of Physics and to humanity. The production of electricity for domestic and industrial use is based on the phenomenon of induction.

We will experimentally observe the phenomenon of induction and deduce the law that governs it. (Faraday's Law).

We set a magnet in motion with respect to a coil connected to a zero galvanometer and observe the following:

• When we bring the magnet closer to the coil, the galvanometer detects an electric current.

• When we remove the magnet from the coil, the direction of the electric current reverses and ceases to exist when we stop the magnet in any position.

• The faster we move the magnet relative to the coil, the higher readings we get from the galvanometer.

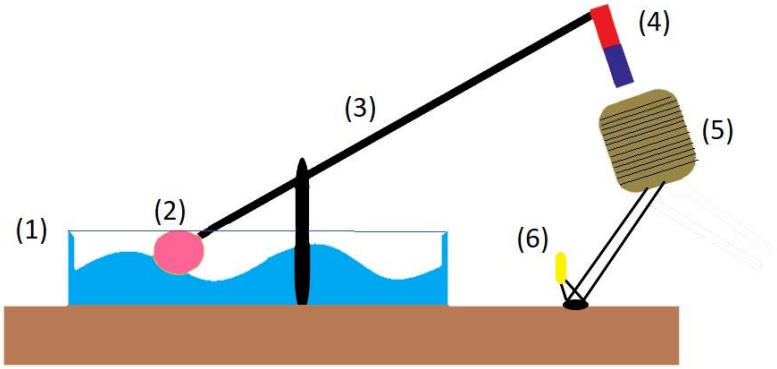
• The induced voltage becomes greater as the number of turns of the coil increases or a stronger magnet is used.

Sea waves can provide a magnet with the kinetic energy it needs so that in a magnet-coil system electricity is produced by induction. The successive waves reaching a floating body to which the magnet is attached cause it to move relative to the coil. The result of this will be the continuous production of electricity.

Considering the observation that the speed at which the magnet enters and exits the coil plays an important role in the electric current produced, shorter period waves are more efficient. This will result in its shorter travel and consequently the greater production of electricity.

Construction and operation of the experimental setup

The construction of the experimental device that converts the energy of sea waves into electrical energy is based on the design in Scheme 1.



Scheme 1. (1) Container of water, (2) Floating body, (3) Metal rod, (4) Bar magnet, (5) Coil, (6) Led (Photodiode)

In more detail, the materials used are:

- Metal rotating mechanism for generating waves in the water
- Plastic container with water
- Metal rod 70cm
- Metal rod 60cm
- Plastic float
- Counterweight
- Coil (24000 turns)
- Rod magnet
- Metal rods adapted to support bases
- Metal connectors
- Metal forceps
- G-type clamps
- Metal rings
- Cables with single, multiple and alligator clips
- Silicon bridge (rectifier)
- Capacitor (10000μF)
- Digital multimeter
- LED lamps (1.5V, 1.8V, 2.4V)

Construction instructions

1. The 60 cm metal rod is fixed horizontally between two vertical metal rods, attached to bases, using metal connectors and rings so that it can rotate freely.
2. A 70 cm metal rod is connected perpendicularly to the middle of the 60 cm rod using a metal connector. The connection point of the 70 cm rod will be about 27-30 cm from one end. The plastic float and the counterweight are attached to this end, while a magnet is attached to the other end.
3. This assembly is placed on one side of the plastic container so that the plastic float can float on the water.
4. On another metal rod with a base, the silicon bridge is connected at a lower point, and the coil is placed higher, using clamp forceps. The coil is positioned so that the magnet can enter and exit it when the experimental setup is set in motion.
5. On the opposite side of the container, a mechanism is installed that, when rotated, creates waves in the water.
6. Wires are used for the connections indicated in the activities.

The construction may require several adjustments and tests before the lesson.

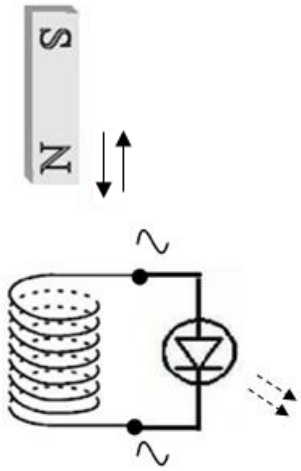
Watching the video of the experiment will be very helpful:
https://www.youtube.com/watch?v=WHqWOB3gn9M

Activity 1

A setup is assembled as shown in Pictures 1, 2. Using a metal rotating mechanism a ripple is created manually in the water. The waves set the plastic float in motion and thus the magnet to which it is connected via the metal rod. When the magnet enters and exits the coil, an induction voltage is created and the led, which is connected in a closed circuit with the coil, turns on and off respectively, because an alternating electric current flows. (Scheme 2)

Picture 1

Picture 2



Scheme 2. Magnet-coil circuit, led.

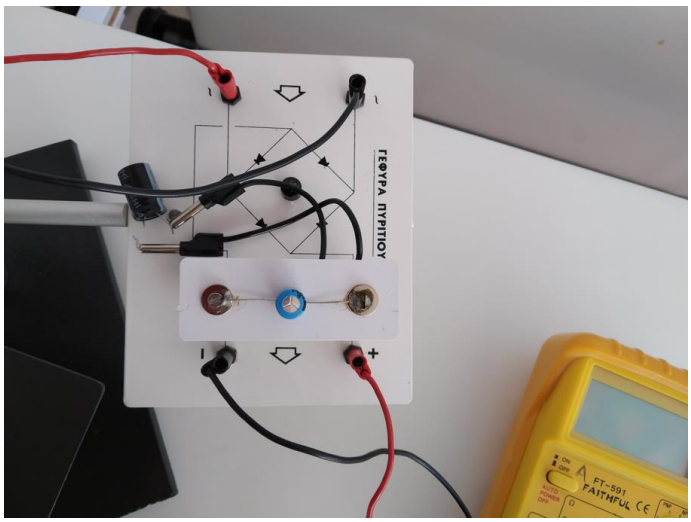
Activity 2

The previous activity is repeated, where according to Scheme 3, a silicon bridge is connected to the coil for full AC rectification. One or two parallel capacitors are connected to the bridge and then we put the device into operation. The voltage at the ends of the capacitors is measured with a digital voltmeter (Pictures 3 and 4) and by extension the electrical energy stored in them (energy obtained from the water ripple).

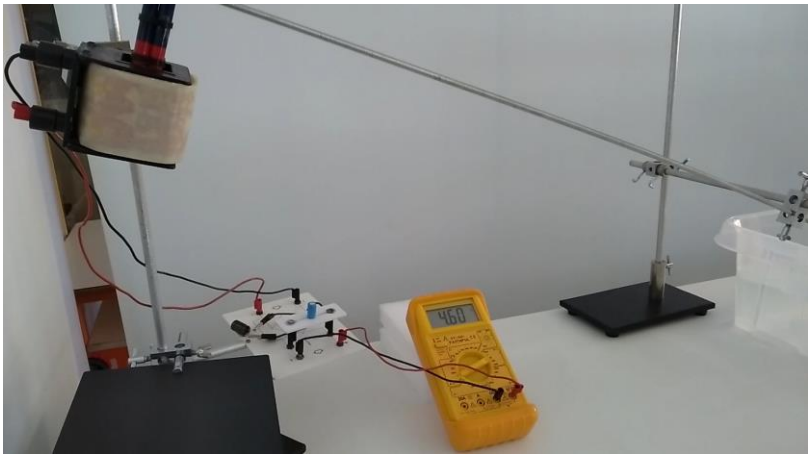
The potential energy U of the charged capacitor is calculated by the formula:

$$U=\frac{1}{2} C V^2$$

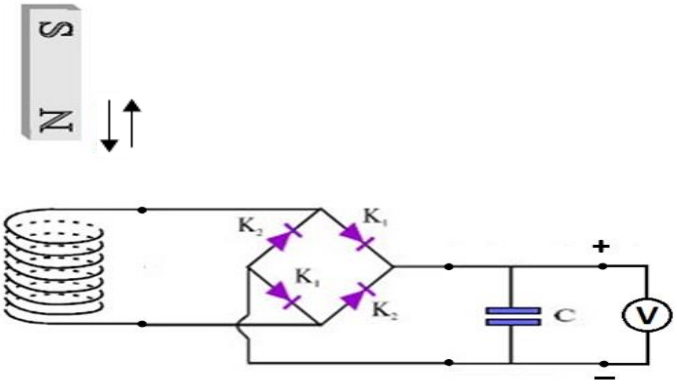
where U the potential energy of the capacitor, C the capacitance of the capacitor, V the potential difference across its ends.



Picture 3



Picture 4

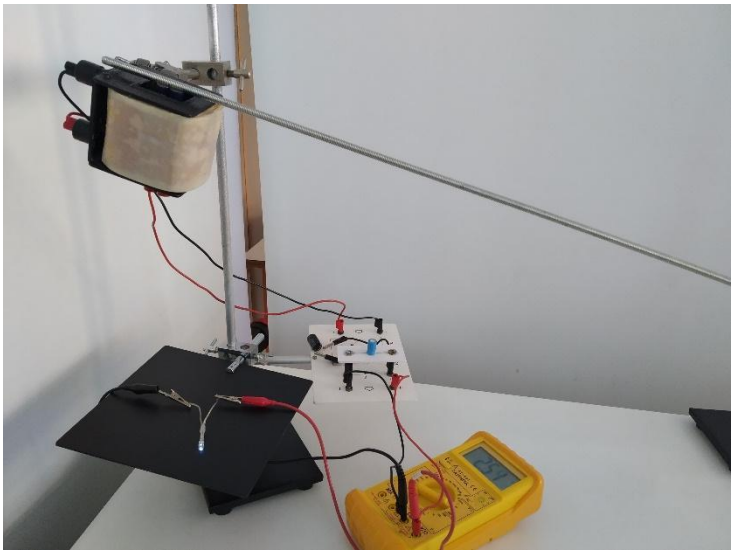


Scheme 3. Magnet-coil circuit, silicon bridge, capacitor, voltmeter.

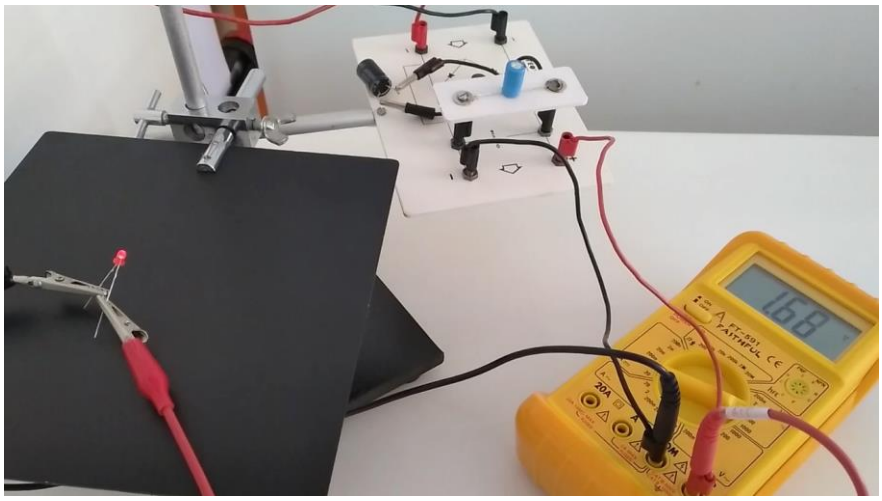
Activity 3

Then, according to Scheme 4, different leds are connected to the capacitor ends of the circuit, which leak direct current due to the rectification. At the same time, the voltage at their ends is measured with the digital multimeter. (Pictures 5, 6). Notice that the LEDs start to light up when the voltage exceeds certain values, which differ for different LEDs.

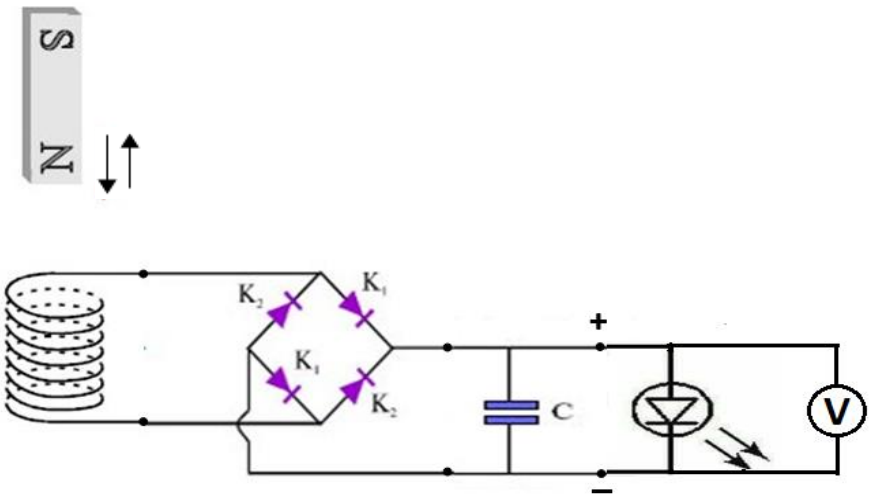
During the LED's light emission, the voltmeter will show a nearly constant value. When the LED disconnected and the device is set in motion again, the voltage will continuously increase. The energy consumption by the LED when it is emitting light, and when disconnected, the energy from the water waves is stored in the capacitor.



Picture 5



Picture 6



Scheme 4. Magnet-coil circuit, silicon bridge, capacitor, led, voltmeter.

Conclusions – Comments

The construction and study of this thesis, following the steps of the exploratory method, leads students:

• to be informed about the existence of natural phenomena that can provide us with mild and exploitable forms of energy that make it possible to solve the energy problems facing the Earth, in an ecological way.

• to investigate sea waves as a renewable energy source, which can be converted into useful electricity.

• to understand physical concepts and quantities as well as the laws that connect them.

• to assemble and operate materials and instruments of the school laboratory to carry out the experiment, so as to draw conclusions and become familiar with the experimental process.

• to have this experiment as a basis for its extension in other areas such as for example the exploitation of the produced[1] electricity for the production of hydrogen from seawater and its use as fuel or the connection of the construction to the computer where with a suitable program it will follow wider data processing.

[1] It is known that electrical energy, like any form of energy, is not produced but transferred from one body (or system of bodies) to another or changes form.

Resources

- Experiment in the virtual laboratory on induction and Faraday's laws:

  https://phet.colorado.edu/sims/html/faradays-electromagnetic-lab/latest/faradays-electromagnetic-lab_all.html
- Watch an illustrated animation about the generation of sea waves and their utilization for electricity production:

  https://www.youtube.com/watch?v=8miWW2QyN_4

Author

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Work sheet

1. In Activity 1, when the induced electric current passes through the LED, it flashes. Why does this happen?

2. How would you connect two LEDs to the ends of the coil and in parallel with each other, so that they:

A. Light up and turn off simultaneously?

B. Light up and turn off alternately?

Perform the circuit layout you suggested.

3. What energy transformations occur during the operation of the device?

Fill in the blanks in the following sentence:

In the experimental setup of the experiment, the .....energy of the water waves is converted into ..... energy of the system (body – metal rod – magnet), which is then converted into ..... energy in the coil.

4. By creating waves in the water in Activity 2, charge the capacitor until the potential difference across its plates is V = 4V. What is the stored potential energy of the capacitor if its capacitance is C = 10,000 μF?

5. Complete the table:

LED	Emission Voltage (Volt)
1. LED (red)	
2. LED (yellow)	
3. LED (green)	
4. LED (white)	
5. LED	
6. LED	

6. During the LED's light emission, the voltmeter shows a nearly constant voltage across the shared terminals of the capacitor and the LED. When the LED is removed, the voltage reading starts to increase. Can you explain why this happens?

“Electricity from sea waves” video link from *Science on Stage Festival* Youtube channel:

https://youtube.com/watch?v=WHqWOB3gn9M&si=m9Rybwan7haF3kBX

The project “Electricity from sea waves” was presented and awarded at Science on Stage Greece (3-4 November 2023). It was also presented at Science on Stage Europe in Turku, Finland (12-15 August 2024).